Positioned For Speed

Positioned For Speed Global Network

Retül

Alphamantis Technologies

PowerTap

VELO Sports Center

Pro Tour Level Team Support

Team Sky

Garmin Sharp

Orica GreenEDGE

Team Europcar

Columbia Pro Cycling

Mtn Qhubeka

Pro Triathlete Support

Craig Alexander

Rachel Joyce

Tim Don

Leanda Cave

USAT Development

Objectives

1. Aerodynamics how and why?
2. How is it measured?
3. How to fit a rider with this information?

Speed Considerations

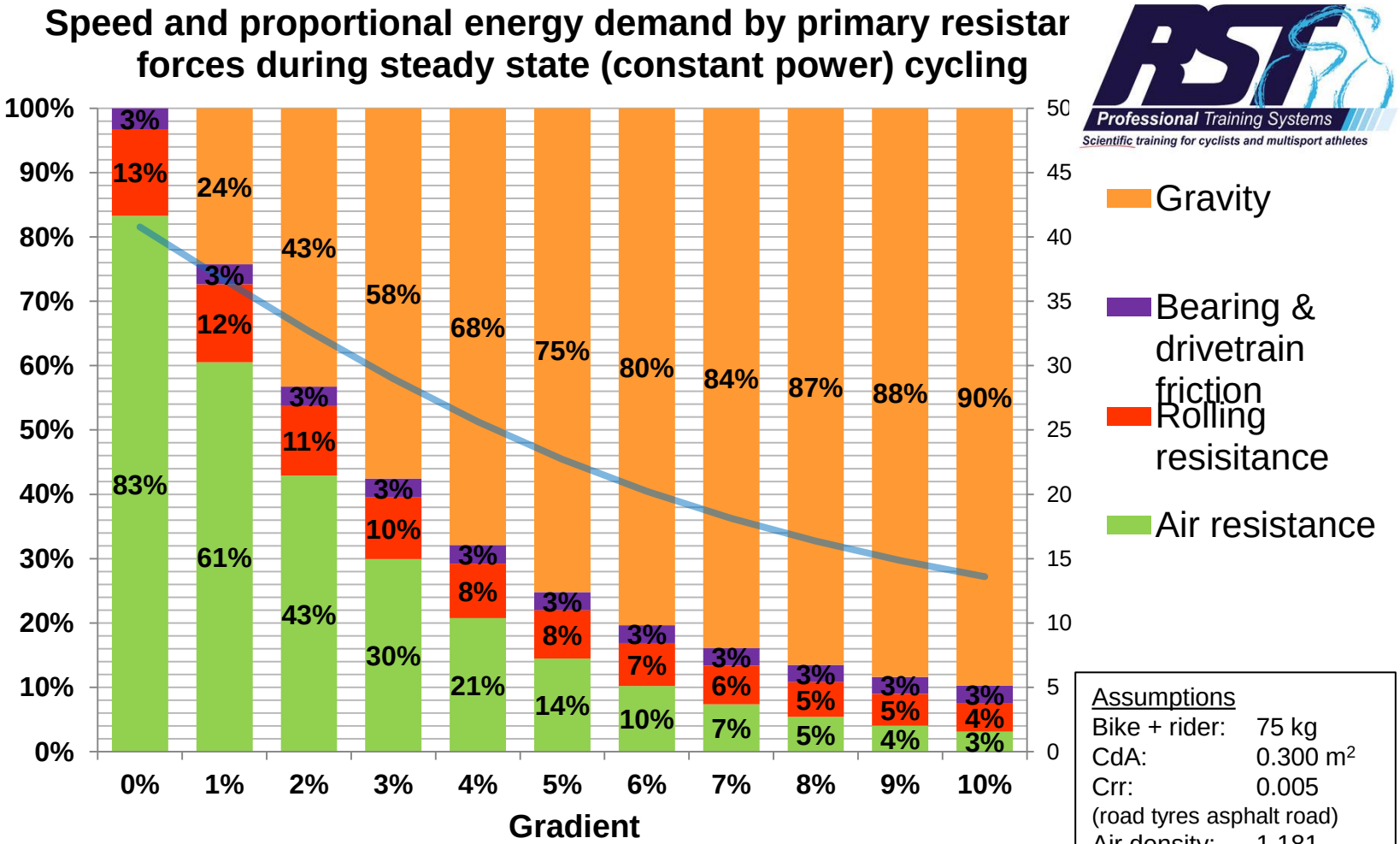
Power

Efficiency

Drag

Aerodynamics

Drag matters!

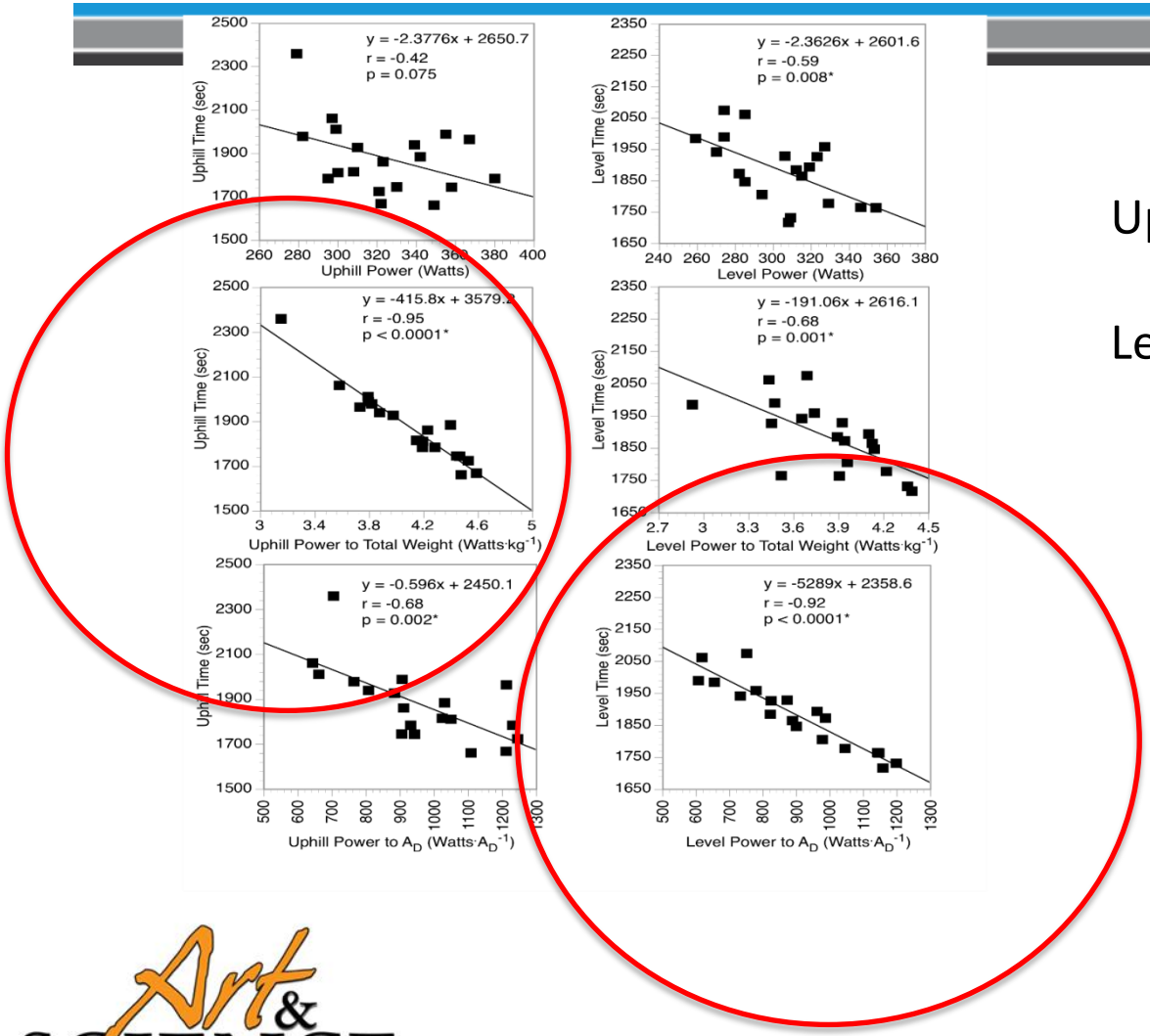


Proportion of energy output overcoming various resistance forces during steady state cycling from flat road (gradient 0%) to very steep climbs (gradient 10%). Speed also shown for various gradients while riding at 300 watts. The progression from air resistance being

Assumptions

Bike + rider:	75 kg
CdA:	0.300 m^2
Crr:	0.005
(road tyres asphalt road)	
Air density:	1.181 kg/m^3
Drivetrain	

Power vs. Drag



Uphill TT time : Power/weight

Level TT time : Power/A_D

PHYSIOLOGIC AND PHYSICAL CORRELATES OF LEVEL AND UPHILL CYCLING PERFORMANCE. University of Colorado, Applied Exercise Science Lab

Aero Drag Components

Drag force

Size	Shape	Air density	Velocity
A_p	C_D	ρ	V^2

What impacts aero drag force?

Major factors

- ↑ Air density (ρ) = ↑ drag
  - ↑ Temperature = ↓ ρ
  - ↑ Altitude = ↓ ρ
  - ↑ Barometric Pressure = ↑ ρ
  - ↑ Humidity = ↓ ρ
- Size of object
  - Effective Frontal Area (A) m^2
- Shape & roughness of object
  - Coefficient of Drag (Cd)
- Speed and type of air flow
  - turbulent & laminar

What can we influence?

Generally not something we can influence, with exception of tracks (e.g. selecting track at altitude, climate controls)

We can reduce Frontal Area by altering position of a rider and equipment changes

We can reduce Cd by altering the shape of the rider and equipment and *consider* strategic roughness elements to impact on nature of the air flow

What impacts aero drag force?

Major factors

- ↑ Air density (ρ) = ↑ drag
  - ↑ Temperature = ↓ ρ
  - ↑ Altitude = ↓ ρ
  - ↑ Barometric Pressure = ↑ ρ
  - ↑ Humidity = ↓ ρ
- Size of object
  - Effective Frontal Area (A) m^2
- Shape & roughness of object
  - Coefficient of Drag (Cd)
- Speed and type of air flow
  - turbulent & laminar

What are we measuring?

- Coefficient of Drag Area (CdA) m^2
  - –Coefficient of Drag (Cd)
  - –x
  - –Effective Frontal Area (A) m^2
- Increase CdA =
  - Slower for same power output
  - More power required to maintain same speed
- Reduce CdA =
  - Faster for same power output
  - Same speed for less power

Frontal Area

- The rider accounts for ~70% of total aerodynamic drag.
- Hence rider positioning is the most important factor for seeking aero gains, but equipment choices are still significant.

Image: www.biketechreview.com

Shape matters!

Shape	Drag Coefficient
sphere	0.47
half-sphere	0.42
cone	0.50
cube	1.05
angled cube	0.80
long cylinder	0.82
short cylinder	1.15
streamlined body	0.04
streanlined half-body	0.09

Measured Drag Coefficients

- These two objects pictured below provide the same amount of aero drag!

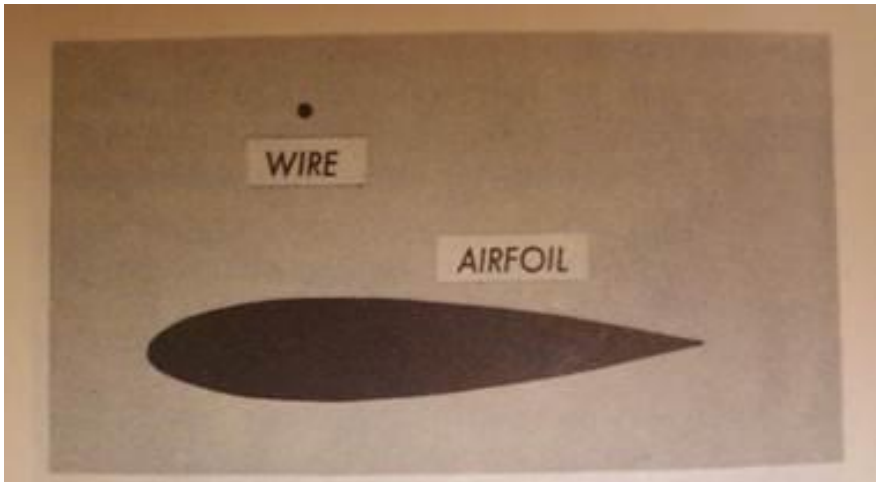


Fig. 72. Relative sizes of wire and streamlined airfoil for the same drag.

Velocity

TABLE 3. Correlations, 95% CI's, and P-values
of drag area or projected frontal area vs. LTT finish time.

Variable *X* vs LTT Finish Time	r	95% CI around r	P-value (r > 0.0)
LTT Power	-0.589	(-0.184, -0.823)	< 0.010
Ad	0.845	(0.634, 0.939)	< 0.001
Ap	0.468	(0.018, 0.761)	< 0.050
Mass (rider)	0.091	(-0.379, 0.524)	> 0.100
DuBois BSA	0.029	(-0.431, 0.477)	> 0.100
Olds-93 Ap(%BSA)	0.018	(-0.440, 0.477)	> 0.100
Olds-95 Ap(%BSA)	0.037	(-0.424, 0.483)	> 0.100
Heil-01 Ap(%BSA)	0.029	(-0.431, 0.477)	> 0.100
Davies-80 Ap(%BSA)	0.029	(-0.431, 0.477)	> 0.100
Pugh-74 Ap(%BSA)	0.029	(-0.431, 0.477)	> 0.100
Olds-95 Ap	0.029	(-0.431, 0.477)	> 0.100
Olds-95 Ap-Swain Corr Factor	0.036	(-0.425, 0.482)	> 0.100
Olds-95 Ap(BRS)	0.029	(-0.431, 0.477)	> 0.100
Heil-01 Ap	0.098	(-0.373, 0.529)	> 0.100
McLean-93 Ap	0.010	(-0.446, 0.462)	> 0.100
Heil-02 Ap(TAP)	0.099	(-0.372, 0.529)	> 0.100

University of Colorado, Boulder. Applied Exercise Science Lab.

Drag Area

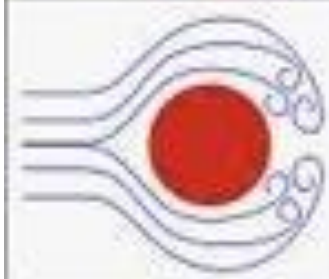
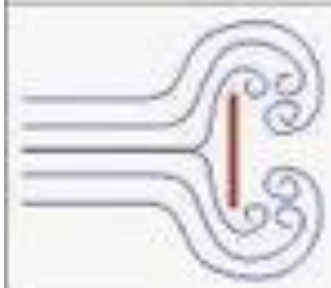
$A_P + C_D$

CdA

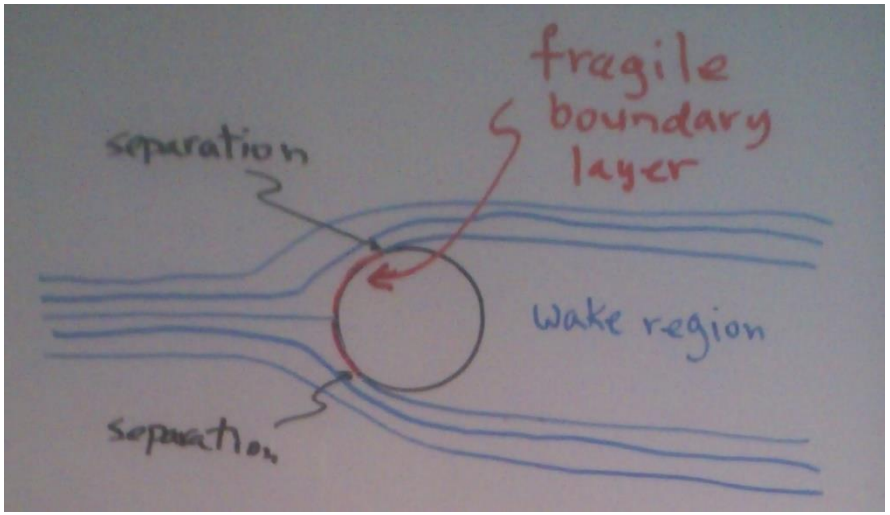
Best Estimation of Drag Force

Skin Friction & Form Drag

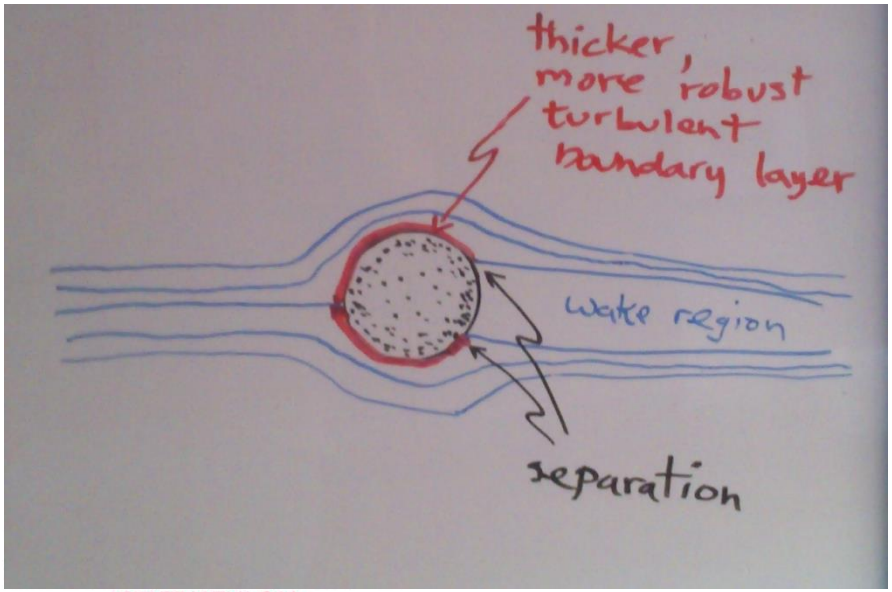
- Skin friction due to boundary layer drag along object's surface
- Form drag due to pressure gradient around object, air flow separation, wake turbulence
- For streamlined objects, skin friction is much greater than form drag
  - Minimal flow separation
- For bluff bodies, form drag is much greater than skin drag
- For cyclist in TT position:
  Form drag ~93%
  Skin friction ~7%

Shape and flow	Form drag	Skin friction
	0%	100%
	~10%	~90%
	~90%	~10%
	100%	0%

How texturing lowers drag



- Smooth Sphere
  - Fragile, laminar boundary layer
  - Early boundary layer separation
  - Large wake region
  - Higher drag for some speeds

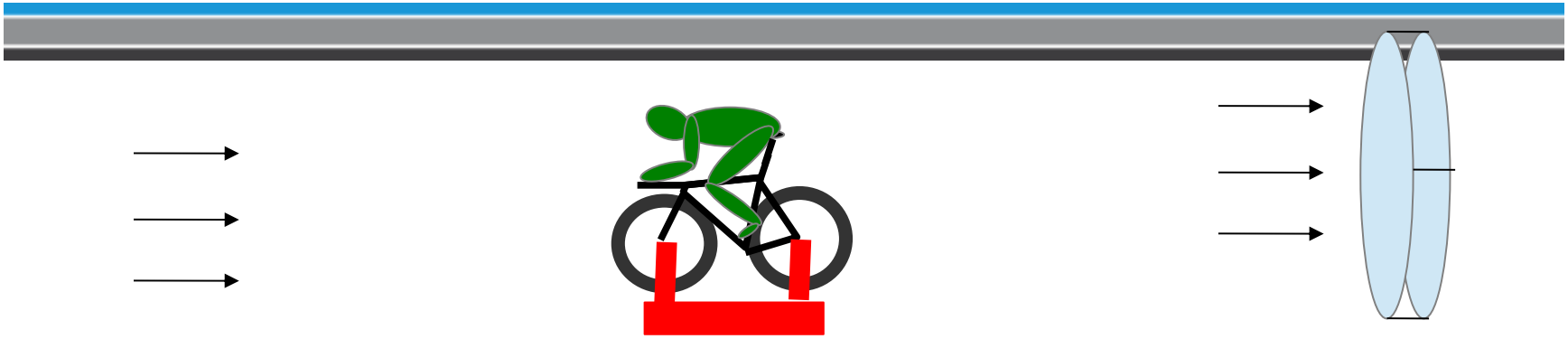


Dimpled Sphere

- Thicker, turbulent boundary layer
- More robust boundary layer
- Delayed boundary layer separation
- Smaller wake region
- Lower drag for some speeds

Measuring Aero Drag

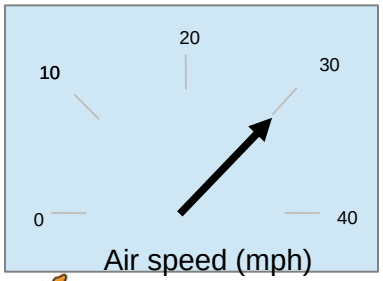
How a Wind Tunnel Works

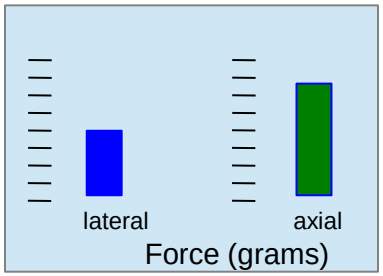


V

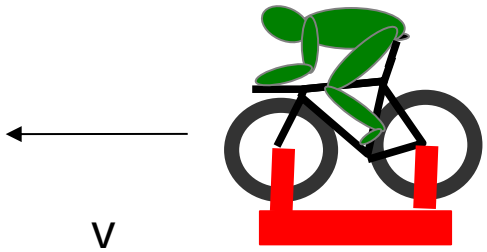
force-measuring
fork mounts

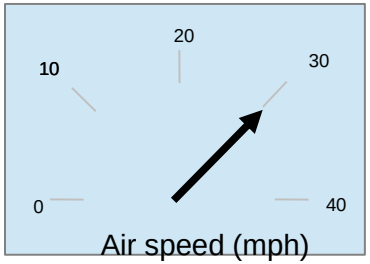
Big Fan!

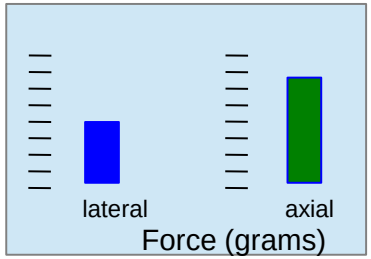




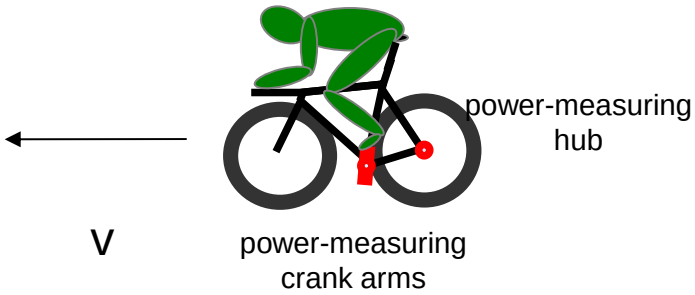
How a Track System Works



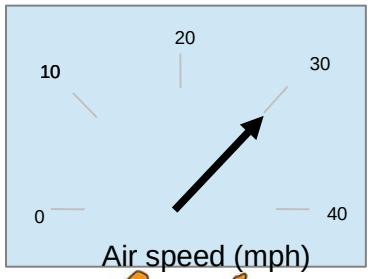


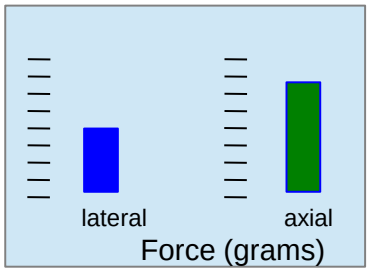


How a Track System Works

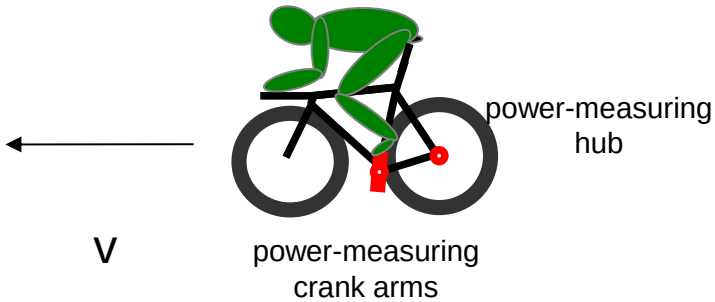


Power = Force * Velocity

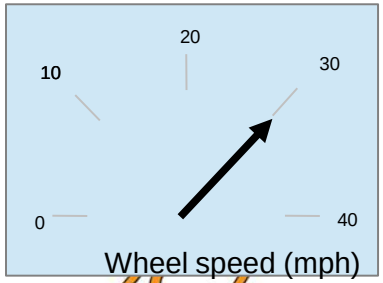


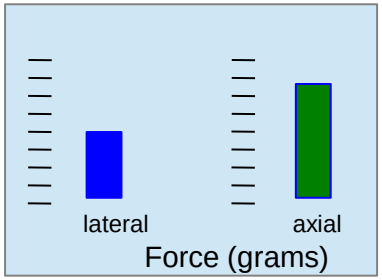


How a Track System Works

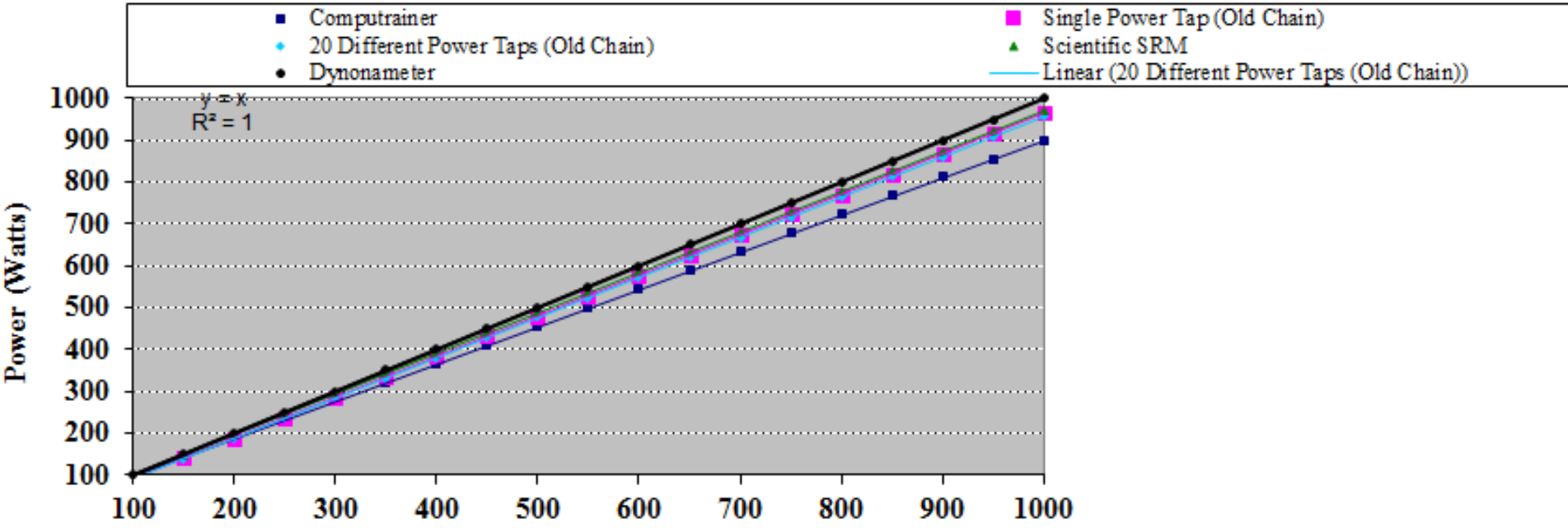


Power = Force * Velocity



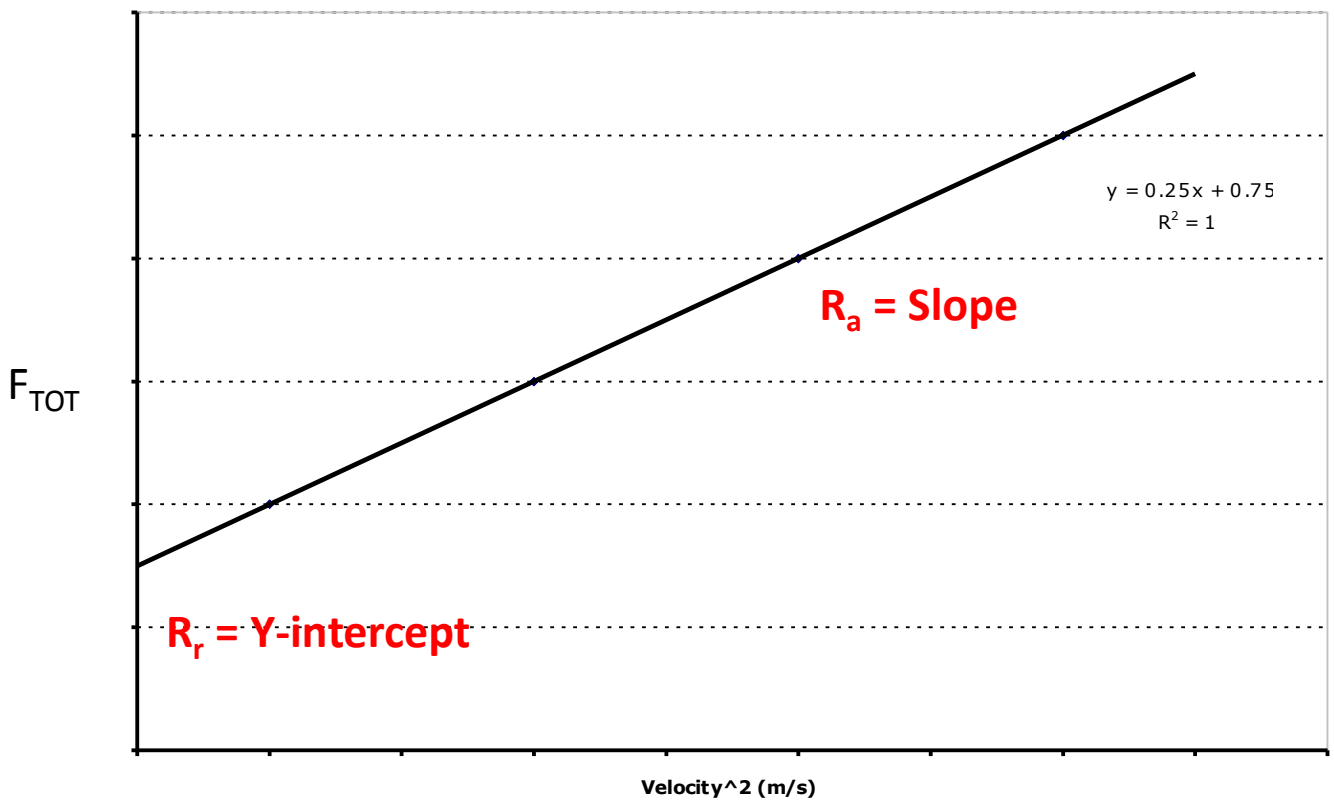


Power Meter Validation



Carver TM ,LIm A. C., Ziewacz, DC and W. C. BYRNES. A mechanical and physiologic validation of a rear hub power meter for cycling. Med. Sci. Sports Exerc., May 2003.

Use power to measure drag



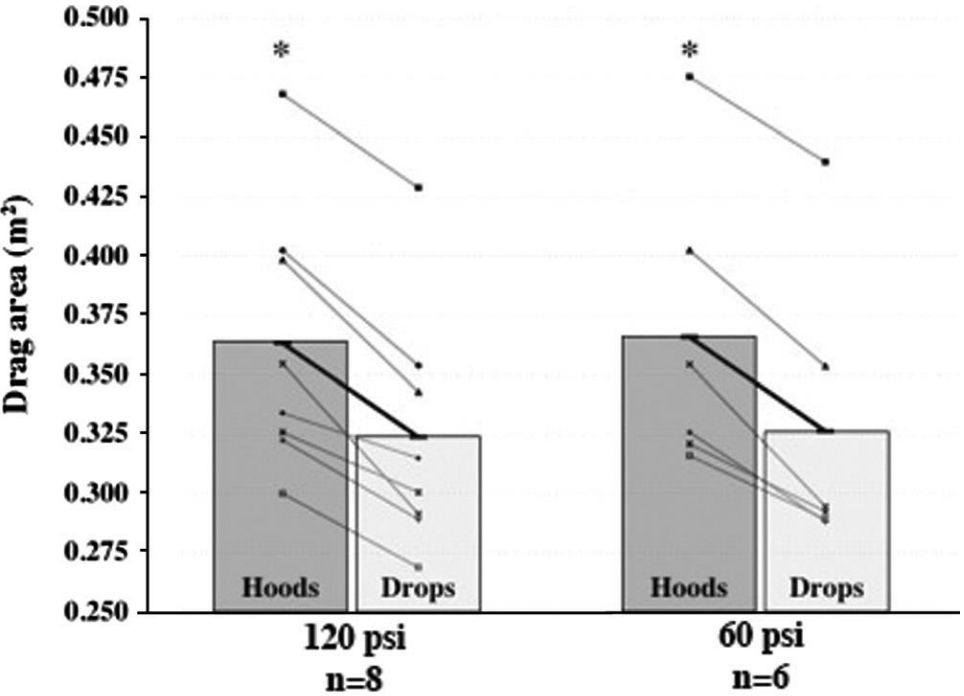
Power= Force * Velocity

Force = Power/Velocity

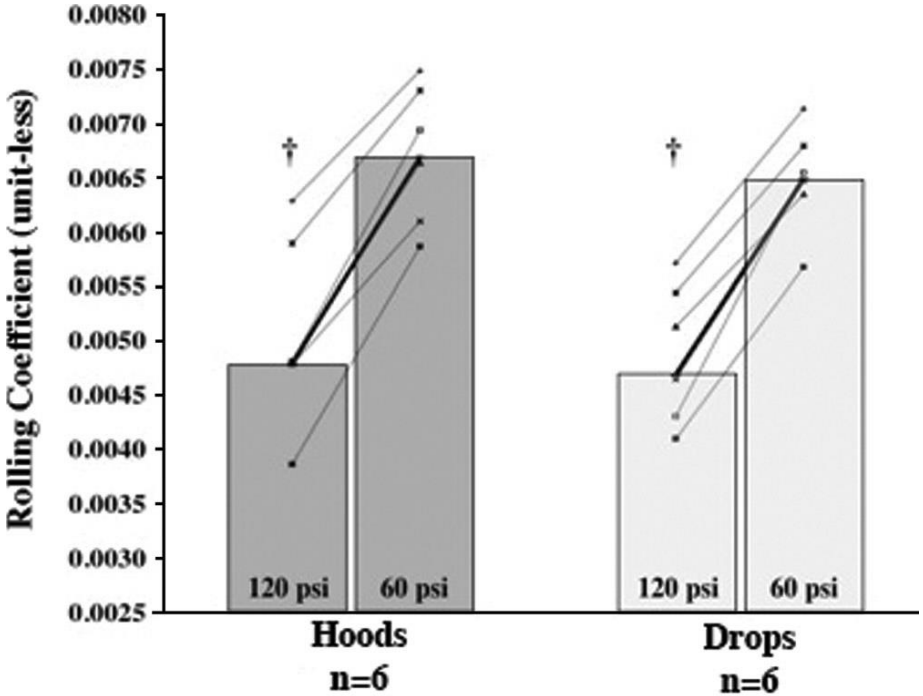
$F_{TOT} = F_a + F_r$

LIM, A. C., E. P. HOMESTEAD, A. G. EDWARDS, T. C. CARVER, R. KRAM, and W. C. BYRNES. Measuring Changes in Aerodynamic/Rolling Resistances by Cycle-Mounted Power Meters. Med. Sci. Sports Exerc., Vol. 43, No. 5, pp. 853–860, 2011.

Validation of Testing Protocol



*Significantly different from 60 psi.



† Significantly different from 60 psi.

LIM, A. C., E. P. HOMESTEAD, A. G. EDWARDS, T. C. CARVER, R. KRAM, and W. C. BYRNES. Measuring Changes in Aerodynamic/Rolling Resistances by Cycle-Mounted Power Meters. Med. Sci. Sports Exerc., Vol. 43, No. 5, pp. 853–860, 2011.

What we measure?

Drag force

Size	Shape	Air density	Velocity
A_p	C_D	ρ	V^2

CDA

Aero Testing Protocol

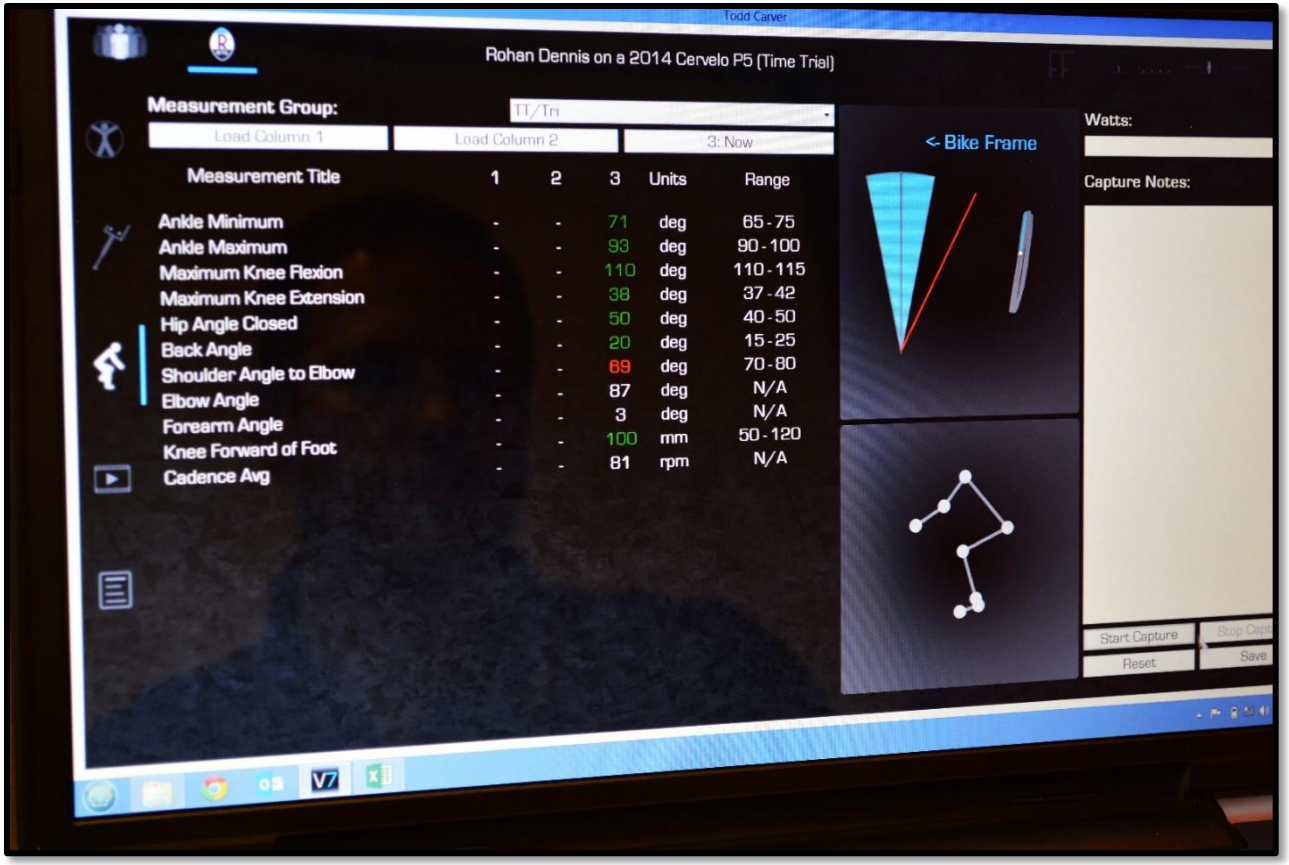
1. Physical assessment.
2. 3D Motion Capture to determine baseline (Retül).
3. Develop a position run list (Retül)
4. Develop an equipment run list
5. Run the positional tests (Alpha Mantis)
6. Run the equipment tests (Alpha Mantis).
7. Develop a list of recommendations for the rider and present a final report.

Positioning & Bike Set-up

Consideration: Proper Positioning (Fit)

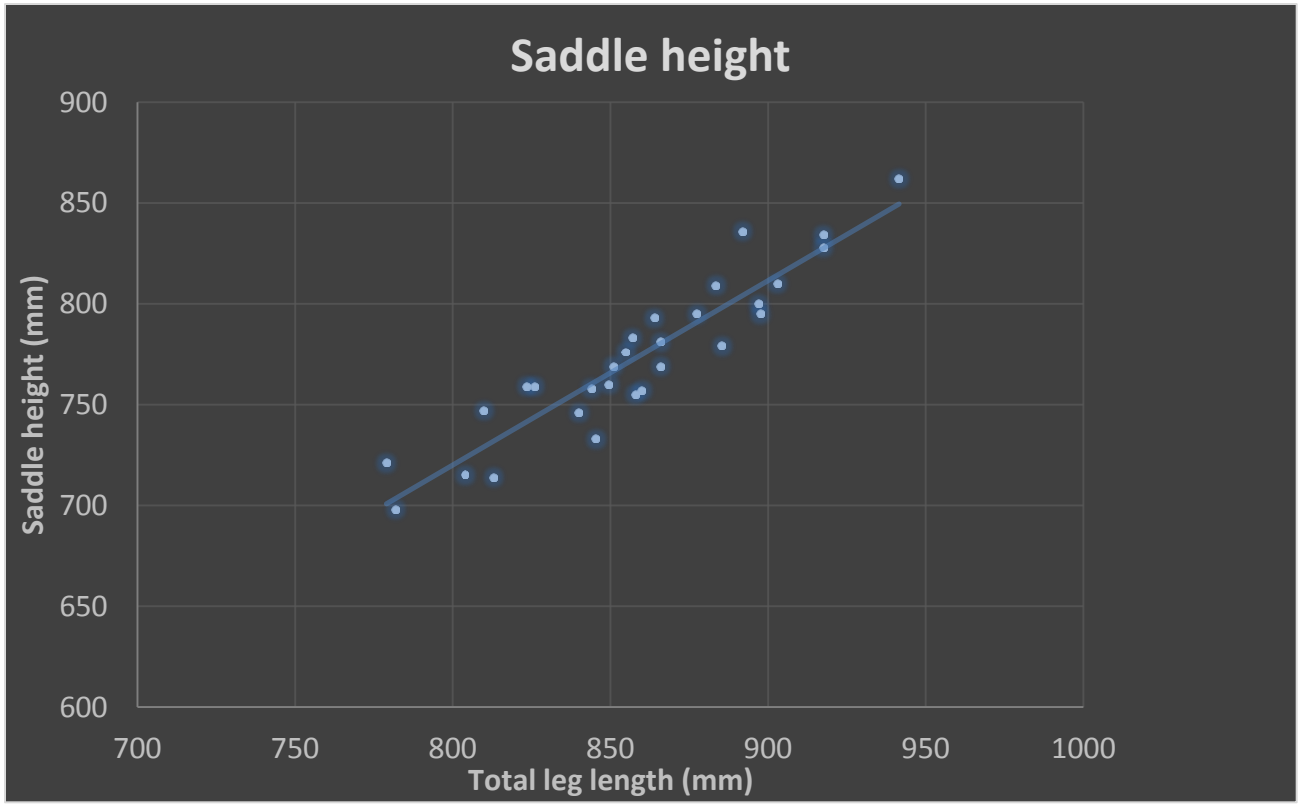
Joint Angles
(mid range)
Alignments
(hips, knees, feet)
Movements
(technique)

Consideration: Proper Positioning (Fit)



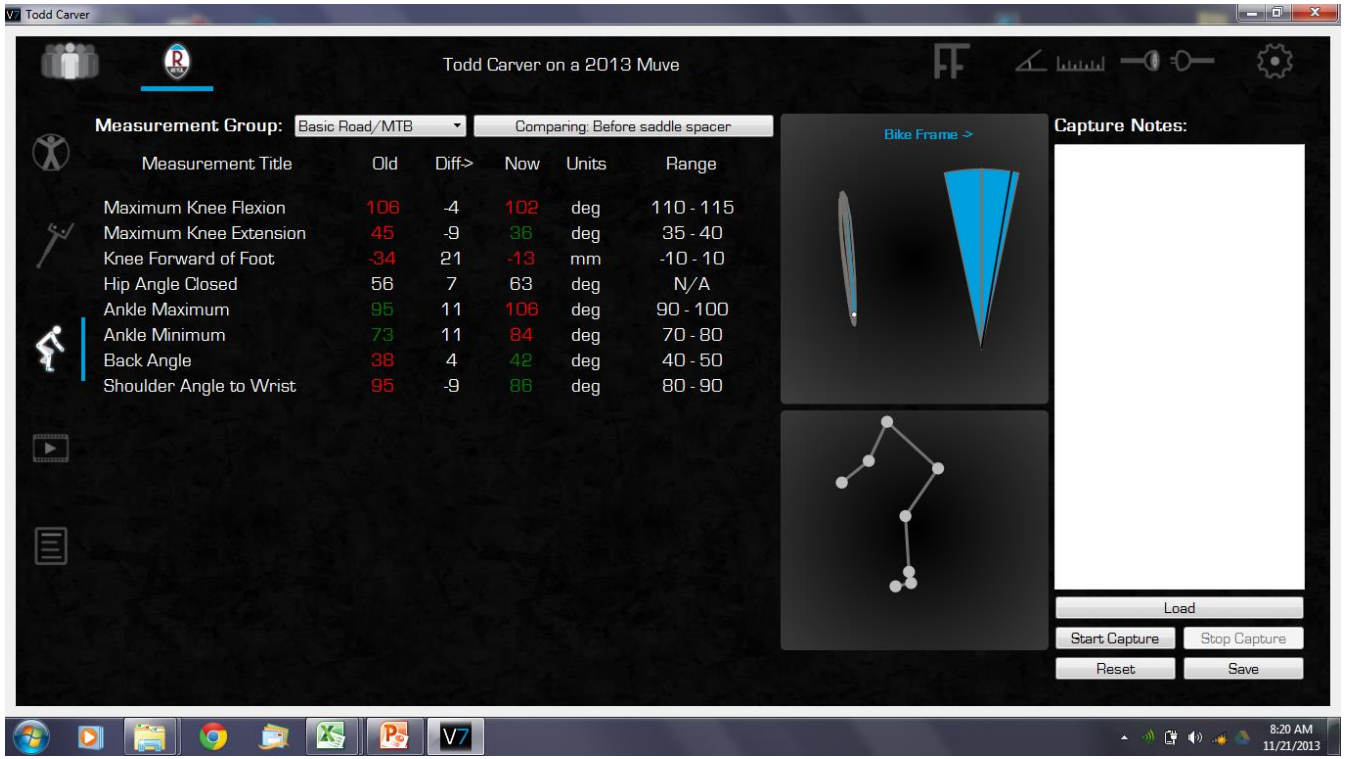
V7

Consideration: Proper Positioning (Fit)



Is Your Fit Unique?

Consideration: Proper Positioning (Fit)



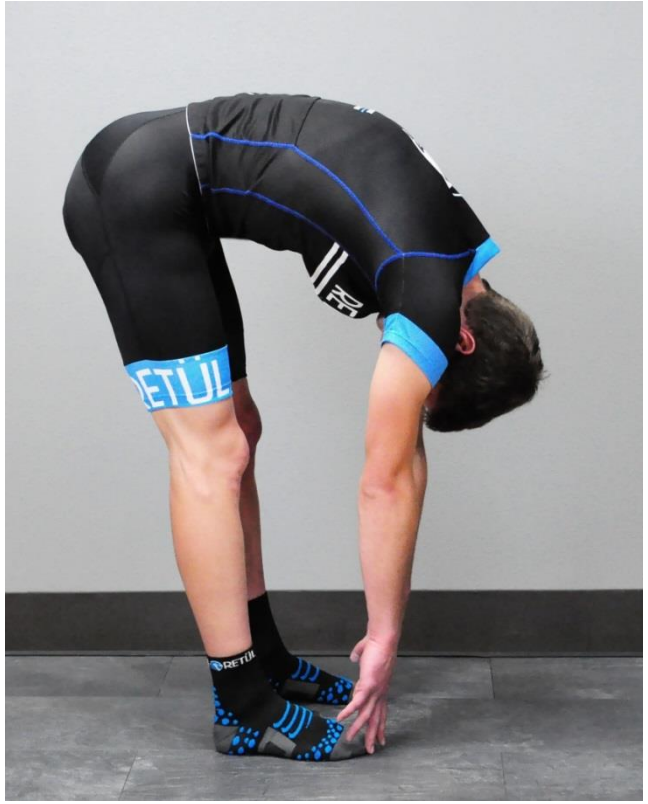
Movement:

-Ankling

-Posture

-Knee Tracking

Consideration: Proper Positioning (Fit)



Athlete Considerations:

-Limitations

-Individuality

-Goals

-Desires

Adaptation / Sustainability

Stability

Duration

Adaptation / Sustainability: Reach

Adaptation / Sustainability: Saddle

Adaptation / Sustainability: Arm Pads

Adaptation / Sustainability: Bar Angulation

Adaptation / Sustainability: Extensions

Relaxed

Torque/Tension

Generating Confidence

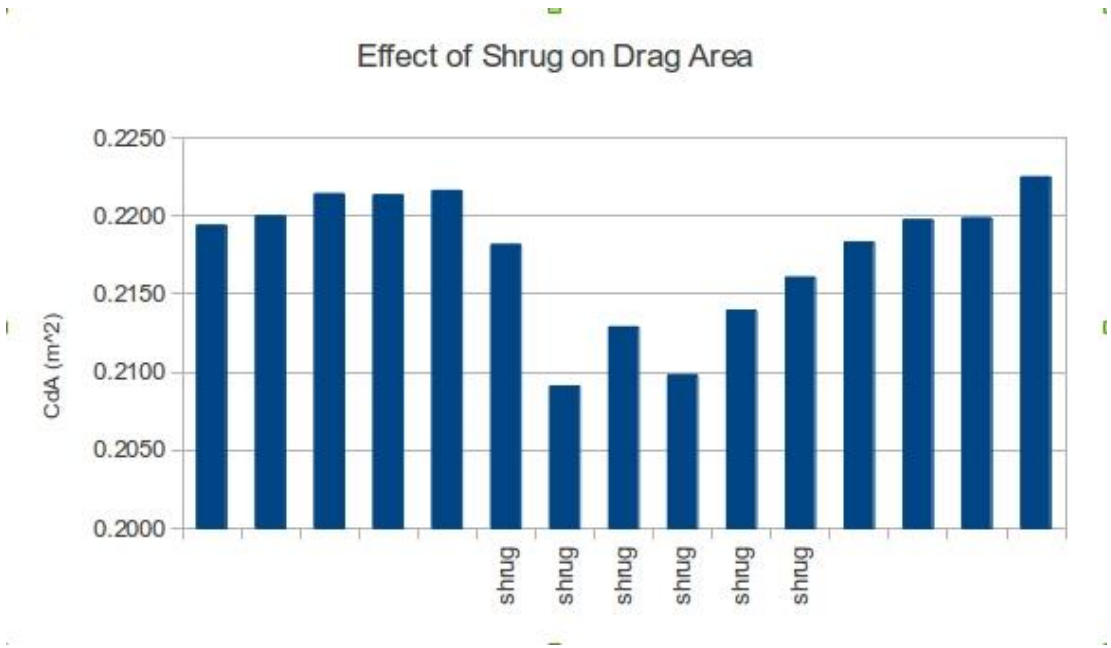
- Establish a solid baseline:
  - 3x20 Rule: 3 runs of 20 laps with +/- 1%
  - Look for sources of inconsistency:
    - Riding position
    - Equipment (brakes rubbing, etc...)
  - Range of CdA should be “right-sized”
    - Fast TT ~ 0.230 m^2
    - Fast Road ~ 0.290 m^2
    - Fast Track Endurance ~ 0.190 m^2

Generating Confidence

- Return to baseline:
  - When a result looks puzzling, too good to be true, or terrible.
  - At least once per test session.

Generating Confidence

- Use A-B-A protocol for change-on-the-fly:
  - Useful for testing posture (shrug)



What's the speed impact?

- Aero rule of thumb
  - $0.01m^2$ change in CdA ~= 1 second per km
    - Mostly flat terrain
    - With a CdA of $0.28m^2$, $0.01m^2$ = 3.6%
  - It may be a bit more or less depending on the actual CdA and speed of the athlete
  - Consider this when setting expectations for improvement

40K Time Savings

300 watts	Standard	Optimized	Savings
Frame	58:29	56:40	1:49
Helmet	58:29	57:51	:40
Wheels	58:29	57:39 (57:26)	:50 (1:03)
Fork	58:29	58:01	:28
Position + Eq	58:29	51:53	6:36

Clean Up Your Bike….

SPECIALIZED

https://www.youtube.com/watch?v=Rli9JyhHs

Summary

- Wind tunnels and Track Aero System use the same principles
- Aero: How efficiently you convert power into speed
- You have direct influence over key aero factors of
  - Frontal area
  - Coefficient of Drag
  - By making bike position and equipment choices
    - Textures and dimples can sometimes help lower drag
- When drag numbers conflict with comfort
  - Give time to adapt
  - Pick comfort